Fraser River Estuary Monitoring

Report on the 1989 Fraser River Sediment Monitoring Program

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REPORT ON THE 1989 FRASER RIVER SEDIMENT MONITORING PROGRAM

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SUMMARY

The quality of sediments in the Fraser River Estuary was examined at six sites by measuring metals, chlorophenols, PCBs, PAHs, phthalate esters, and organochlorine pesticide concentrations. The purpose of the study was to obtain background information on the concentration of a number of metal and organic compounds in the sediments, to determine if sediments collected in 1989 following freshet were the same as those collected just prior to freshet in 1985 and 1987, and to determine if Water Quality Objectives were achieved.

Concentrations of metals measured in sediments in 1989 were usually higher than found in the sediments from the same sites in 1987; this may be explained by the fact that the sediment particle size in 1989 was finer than in 1987, that different laboratories and techniques were used in the two years, or that the time of year that samples were collected was a factor. Finer sized particles have a larger surface area per unit weight onto which contaminants can be sorbed, so the higher metal concentrations may be attributable to this phenomenon rather than to increased anthropogenic inputs of metals.

The one exception to higher metal concentrations in 1989 compared to 1987 was lead, for which 1989 concentrations were actually lower than in 1987. This result suggests that the elimination of lead from gasoline may be having a positive environmental impact.

It is suspected that the particle size of the sediments is related to the time of year that the sediments were collected. In fact, we concluded that chromium, lead, nickel, and zinc concentrations also may reflect differences due to the time of year that the samples were collected. This was based on whether patterns for increases or decreases of the concentrations of these metals was the same in the 1987 and 1989 surveys. Such a conclusion could not be drawn for cadmium, copper, or mercury.

All three forms of chlorophenols (tri-, tetra-, and penta-) were less than the detection limit (0.005 µg/g) at all six sites. A lower detection limit (0.003 µg/g) was used in the 1987 survey and

so direct comparisons between these two years cannot be made. However, the 1987 data were lower than concentrations found in 1985 at the same sites. It is not possible to determine with complete certainty if the Water Quality Objective of a maximum 0.01 µg/g chlorophenol in sediment was achieved in the 1989 survey due to the detection limits used.

PCBs could not be detected (<0.01 µg/g) at any of the sites in this survey as was the case in 1987 for the same sites when the detection limit was 0.02 µg/g. The Water Quality Objective for PCBs in sediments of 0.03 µg/g maximum was achieved at all the sites in this survey.

Measuring phthalates in the environment is difficult due to their ubiquitous nature which produces sample contamination. Concentrations of phthalates measured in this survey were usually below the detection limit for the particular phthalate or below the level of contamination cited for each phthalate from the quality control data. Exceptions to this were the maximum concentrations of di-n-butyl phthalate, di-n-octyl phthalate, and bis (2-ethylhexyl) phthalate. Apparent Effects Threshold (AET) values for benthic aquatic life have been developed for Puget Sound Department of Ecology for phthalate esters. All phthalate ester concentrations measured in the Fraser River sediments above contamination levels were below the lowest AET concentrations.

Most of the individual PAHs were below the varying detection limits. High values relative to the detection limit were determined for acenaphthylene, anthracene, and benzo(a)pyrene, although the highest PAH concentrations were 10% or less of the AET for Puget Sound sediments. This means that there is no immediate concern for the concentration of PAHs in Fraser River Estuary sediments.

The concentrations of organochlorine pesticides in Fraser River sediments were less than varying detection limits except for DDD, DDE, and DDT. Only DDE was detected at more than one site, while only DDD was sufficiently high (0.005 µg/g in one sample from one site) relative to the detection limit (0.001 µg/g) to be noteworthy. DDT was used in the past as an agricultural pesticide but its use has been banned for many years. Its presence, and that of its breakdown products, likely reflects its historic widespread use. The low concentrations measured indicate that DDT is becoming degraded.

TABLE OF CONTENTS

	Page
SUMMARY	i
TABLE OF CONTENTS	iii
LIST OF TABLES	v
LIST OF FIGURES	vi
1. INTRODUCTION	1
1.1 Site Selection	1
1.2 Provisional Water Quality Objectives	2
2. MATERIALS AND METHODS	3
2.1 Field Methods	3
2.2 Analytical Methodology	3
2.2.1 Sample Preparation and Storage	3
2.2.2 Metals	4
2.2.3 Chlorinated Phenols	4
2.2.4 PCBs, Organochlorine Pesticides, and Phthalate Esters	5
2.2.5 Polynuclear Aromatic Hydrocarbons	5
2.2.6 Moisture	6
2.2.7 Total, Organic, and Inorganic Carbon	6
2.2.8 Particle Size	6
2.2.9 Total Volatile Residue	6
2.3 Quality Assurance/Quality Control	7
3. RESULTS AND DISCUSSION	9
3.1 Physical Characteristics of Sediments	9
3.1.1 Particle Size	9
3.1.2 Total Organic Carbon	10
3.2 Metals and Metalloids	10
3.2.1 Arsenic	11
3.2.2 Cadmium	12
3.2.3 Chromium	13
3.2.4 Copper	14
3.2.5 Lead	15
3.2.6 Mercury	16
3.2.7 Nickel	16
3.2.8 Zinc	17
3.2.9 Conclusions	18

TABLE OF CONTENTS (CONTINUED)

		Page
3.3	Chlorinated Phenols and PCBs	19
	3.3.1 Quality Assurance / Quality Control	19
	3.3.2 Values in Sediments	20
	3.3.3 Conclusions	20
3.4	Phthalate Esters	21
	3.4.1 Quality Assurance / Quality Control	21
	3.4.2 Values in Sediments	22
	3.4.3 Conclusions	23
3.5	Polycyclic Aromatic Hydrocarbons (PAHs)	24
	3.5.1 Quality Assurance / Quality Control	24
	3.5.2 Values in Sediments	25
	3.5.3 Conclusions	26
3.6	Organochlorine Pesticides	26
	3.6.1 Quality Assurance / Quality Control	27
	3.6.2 Values in Sediments	27
	3.6.3 Conclusions	28

REFERENCES 29

LIST OF TABLES

Table		Page
1	Physical Characteristics of Fraser River Sediments	35
2	Summary of Metals in Sediments at Site MS-1, Fraser River at Barnston Island	37
3	Summary of Metals in Sediments at Site MS-2, Fraser River at Sapperton Channel	38
4	Summary of Metals in Sediments at Site NA-1, Fraser River at the Upper North Arm	39
5	Summary of Metals in Sediments at Site NA-2, Fraser River at McDonald Slough	40
6	Summary of Metals in Sediments at Site MA-1, Fraser River at Annacis Island	41
7	Summary of Metals in Sediments at Site MA-2, Fraser River at Ewen Slough	42
8	Summary of Chlorophenols and PCBs in Fraser River Sediments	43
9	Summary of Phthalate Esters in Fraser River Sediments	44
10	Summary of PAHs in Fraser River Sediments	45
11	Summary of Organochlorine Pesticides in Fraser River Sediments	47

LIST OF FIGURES

Figure		Page
1	1989 Sediment Sampling Sites	32
2	Accuracy Data For Sediments - 1989	33
3	Comparison of Duplicate Analyses For Sediments	34

1. INTRODUCTION

On April 1, 1986, a five-year agreement was concluded between the Fraser River Harbour Commission and the B.C. Ministry of Environment (MoE). The agreement related to carrying out monitoring in the Fraser River Estuary area, based on a report prepared by the Working Committee on Fraser River Estuary Monitoring (1984). The estuary area under study is from Kanaka Creek downstream.

Monitoring during 1989 was directed towards determining the quality of sediments, fish, and other biota in Boundary Bay, as well as to collect additional data for sediments from the Fraser River. The data for the Fraser River sediment sampling are reported here, with samples having been collected from those sites shown on Figure 1.

The purpose of the monitoring was to:

1. Determine the levels of metals and organic contaminants in the sediments in the Fraser River. Organic contaminants had not been measured in sediments in previous surveys.

2. Determine the degree to which the values meet provisional Water Quality Objectives for the Fraser River (Swain and Holms, 1985).

3. Determine if values measured immediately following the spring freshet in 1989 were different from those measured just prior to freshet in 1987.

1.1 SITE SELECTION

Six sites were sampled for sediments in the Fraser River area during August 1989. The sites are shown in Figure 1, and were previously sampled in 1985 (Swain 1986) and 1987 (Swain and Walton 1988).

1.2 PROVISIONAL WATER QUALITY OBJECTIVES

The MoE is currently establishing provisional Water Quality Objectives on a site-specific basis. One area where the Objectives have been published is for the Fraser River Estuary.

Provisional Objectives which are applicable for the results from this survey are (Swain and Holms, 1985):

PCBs: 0.03 µg/g (dry-weight) maximum in bottom surface sediments, generally considered the top 2.5 cm layer of sediment

Chlorophenols: 0.01 µg/g (dry-weight) maximum in bottom surface sediments, generally considered the top 2.5 cm layer of sediment. Chlorophenols are considered to be the sum of tri-, tetra-, and pentachlorophenol.

2. MATERIALS AND METHODS

2.1 FIELD METHODS

Sediments were monitored at six sites in the Fraser River Estuary (Figure 1), two sites each in the Main Stem (MS), North Arm (NA), and Main Arm (MA). Sediments were collected with a Petite Ponar dredge, and emptied into a glass tray, if possible. Large pieces of bark or wood residue were were picked out from the inorganic fraction of sediment. Five discrete samples were collected from each site, and placed into 250 mL glass jars. The results reported herein are for up to five samples per site, since available resources did not permit all the samples to be analyzed.

The tray and scraper were rinsed with on-site water between samples. Between sites, the tray and scraper were rinsed with tap water carried in glass jars, then acetone, and finally hexane. The utensils were then allowed to air dry. At stations where the glass tray could not be used, care was taken to ensure that the sediment had not contacted plastic or wood. The results reported are for discrete, not composite samples.

All sediments were kept as cool and refrigerated as possible, prior to delivery to the laboratory.

2.2 ANALYTICAL METHODOLOGY

Much of what follows has been taken directly from the report prepared for the Fraser River Harbour Commission by the contract laboratory, Analytical Services Laboratory Ltd. (ASL).

2.2.1 SAMPLE PREPARATION AND STORAGE

When the sediment samples were received at the laboratory, they were catalogued and kept cool until analyzed. The samples were prepared in a clean environment dedicated to this project. Individual sediment samples were blended to uniformity and sub-sampled to ensure a representative portion was taken for analysis.

2.2.2 METALS

All samples were analyzed using procedures outlined in Tetra Tech (1986). Specifically, a representative sub-sample (5 to 10 grams wet weight, depending upon the moisture content and the uniformity of the sub-sample) of homogenized sediment was digested using a combination of nitric and hydrochloric acids. The resulting extracts were analyzed using atomic absorption techniques, as outlined in the following table.

Element	Instrument Detection Mode
As,Cd, Pb	Perkin Elmer Model MHS-20 hydride generation system coupled to a Model 2380 AA dual beam spectrophotometer equipped with automatic background correction.
Cr,Cu, Fe, Mn, Mg,Mo, Ni, Zn	Perkin Elmer Model P-40 inductively coupled argon plasma spectrograph.
Hg	Pharmacia Model U.V. mercury monitor with a 30 cm absorption cell.

2.2.3 CHLORINATED PHENOLS

A representative portion of each sample (25 to 40 grams wet weight, depending upon the moisture content and the uniformity of the sub-sample) was extracted using a modification of a technique published by Tetra Tech (1986). This procedure involves the soxhlet extraction of the sample with acidified hexane/acetone followed by solvent partitioning. The crude extract was then cleaned-up using Sephadex QAE-A25 ion exchange resin (Renberg, 1974). The resulting extracts were then derivatized using heptafluorobutyric anhydride and analyzed by capillary gas chromatography with electron capture detection, under the following conditions:

Instrument:	Hewlett Packard Model 5890A
Columns:	HP-1, 25 metres long by 0.32 mm i.d. by 0.17 µm film thickness HP-5, 25 metres long by 0.32 mm i.d. by 0.17 µm film thickness
Oven:	100 °C hold for 1 minute, then 5 °C/minute to 200 °C, hold for 5 minutes.

2.2.4 PCBs, ORGANOCHLORINE PESTICIDES, AND PHTHALATE ESTERS

A representative portion of each sample (the same 25 to 40 grams wet weight used for the chlorophenol analysis) was extracted using a modification of a technique published by Tetra Tech (1986). This procedure involves the soxhlet extraction of the sample with acidified hexane/acetone followed by solvent partitioning. The crude extract was split for subsequent analysis of chlorophenols and another portion was then cleaned-up by alumina column chromatography producing various fractions containing the PCBs, pesticides, and phthalate esters. The resulting extracts were analyzed using capillary gas chromatography equipped with dual column/dual electron capture detection under the conditions outlined in Section 2.2.3, with the following modifications:

Oven:	Fraction 1- 150 °C hold for 3 minutes, then 3 °C/minute to 210 °C, hold for 7 minutes Fraction 2- 200 °C hold for 1 minute, then 3 °C/minute to 230 °C.
Injection:	2 µL (splitless)

2.2.5 POLYNUCLEAR AROMATIC HYDROCARBONS

A representative portion of each sample (a portion of the same 25 to 40 grams wet weight used for the other organics analyses) was extracted separately using a modification of Procedure 21.001 (AOAC, 1984). This involves the saponification of the sample with ethanolic potassium hydroxide followed by solvent partitioning into iso-octane. This crude extract was then subjected to a clean-up

procedure using phosphoric acid and solvent partitioning between iso-octane and dimethyl sulfoxide. A further clean-up procedure using silica gel column chromatography (EPA Method 610, U.S. EPA, 1984) was also employed. The resulting extract was then analyzed by capillary gas chromatography with mass spectrometer detection, under the following different conditions than outlined in Sections 2.2.3 and 2.2.4.

Instrument:	Hewlett Packard Model 5880
Oven:	80 °C, hold for 1 minute, then 7 °C/minute to 260 °C , hold for 10 minutes.

2.2.6 MOISTURE

A representative portion of the sample (5 to 10 grams) was dried to a constant weight at 105 °C. Moisture was then determined gravimetrically by measuring weight loss upon drying.

2.2.7 TOTAL, ORGANIC, AND INORGANIC CARBON

A representative portion of each sample (5 to 10 grams) was leached with hydrochloric acid to remove carbonates and then analyzed for organic carbon using a Leco induction furnace. Total inorganic carbon was determined as the difference between total and organic carbon.

2.2.8 PARTICLE SIZE

Representative portions of each sample (5 to 10 grams) were dry sieved in accordance with Tyler (1980), and the fine materials determined by pipette method (Tanner and Jackson, 1947).

2.2.9 TOTAL VOLATILE RESIDUE

Determined gravimetrically after igniting the sample at 550 °C for one hour and cooling in a vacuum desiccator.

2.3 QUALITY ASSURANCE/QUALITY CONTROL

The following is based upon information provided by ASL Laboratories.

Extensive quality assurance measures were taken to ensure the highest level of precision and accuracy was maintained. All analyses were performed using accepted procedures and included the concurrent analysis of reagent blanks, sample duplicates, analyte spikes, and certified reference materials, where available. Further detailed discussion of the precision and accuracy for each type of analyses is included in the following chapter.

The U.S. EPA define Quality Assurance (QA) as the "total program for assuring the reliability of monitoring data". Quality control (QC) is limited to "the routine application of procedures for controlling the measurement process." QA is concerned primarily with the tools of the measurement system. Reagents of the highest quality were used and checked for purity, strength, deterioration with time, and contamination. Class A volumetric glassware was thoroughly cleaned and calibrated when necessary. Balances were checked frequently with certified weights and records maintained. All instruments were calibrated on a routine basis, with the maintenance of appropriate standards and operational logs on performance.

Extensive QA measures were taken to ensure the highest level of precision and accuracy was maintained. All analyses were performed using accepted procedures and included the concurrent analysis of reagent blanks, sample duplicates, analyte spikes, and certified reference materials, where available. Further detailed discussion of the precision and accuracy for each type of analyses is included in the following chapter.

Accuracy was determined for metals by measuring levels in three separate certified reference sediment samples; two of these were marine sediments prepared by the National Research Council of Canada and one was an estuarine sample from the National Bureau of Standards in the USA. Reference materials were not available for organics.

Precision was determined for metals by running eight digestion blanks and 16 duplicate analyses of individual samples. For organic analyses, 10 extraction blanks and 10 analyte spikes were tested, as well as 11 duplicate analyses of individual samples.

For metals, only minor amounts of iron and magnesium were detected in the digestion blanks, indicating very little inherent contamination from the analytical procedure. Further discussion is included for each characteristic in the appropriate section. Where the discussion relates to the precision of duplicate analyses, the percent difference between values is calculated as the difference divided by the smaller of the two values. This produces larger numbers emphasize precision more than if the average or maximum values were used in the calculation.

For the organic analyses, only trace amounts of phthalates were consistently detected in the extraction blanks. Considering the number of phthalate sources, their relative abundance and mobility, this was not unexpected. In fact, the only other organic contaminant found in the extraction blank was the PAH, acenaphthylene, in one of the ten extraction blanks. Further discussion is included for each characteristic in the appropriate section.

3. RESULTS AND DISCUSSION

In the following discussion, when at least one-half of the results are above the detection limit, average values and corresponding standard deviations have been calculated. In cases where values are less than the minimum detectable concentration, the absolute value of the detection limit has been used to calculate average values. If more than one-half of the results are below the detection limit, average values and standard deviations are not calculated since there is too much uncertainty with so many values less than detection.

Values cited for sediments are as dry-weight, unless otherwise noted. The laboratory (ASL) reported that no technical problems were encountered with any of the sediment analyses.

When comparisons are made to the 1987 survey, it should be noted that a different laboratory performed the analyses at that time, generally using different analytical techniques.

3.1 PHYSICAL CHARACTERISTICS OF SEDIMENTS

For the purpose of this report, the following characteristics have been classified as being physical characteristics. These are particle size, moisture content, total organic carbon, total inorganic carbon, and total volatile residue. A summary of these data are in Table 1.

There were no QA/QC data generated for the physical characteristics by the laboratory.

3.1.1 PARTICLE SIZE

The size of the sediment particles generally got smaller proceeding in a downstream direction. The largest quantity of coarsest particles were found in the Main Stem, with the largest quantity of finest sized particles being found at the downstream sites in each of the Main and North arms. This is the same finding as

in 1987 (Swain and Walton 1988) and 1985 (Swain 1986) at the same sites.

It is generally believed that particle size can be important with respect to contaminant concentrations in sediments. Finer materials have the potential for higher contaminant levels, since fine grained particles give a larger surface area per unit area to which contaminants are easily sorbed.

3.1.2 TOTAL ORGANIC CARBON

Total organic carbon (TOC) is indicative of the amount of organic matter present in sediments. High concentrations of organic matter and humic content increase adsorption and binding capacities of bottom sediments.

The mean TOC concentration was highest in the North Arm sediments, with the highest mean concentration of 11 100 µg/g being found in the sediments from Site NA-2 in McDonald Slough in the North Arm. This fact, in conjunction with the particle size distribution, would lead one to anticipate that the highest metal concèntrations will be found at the McDonald Slough site, all other factors being equal.

3.2 METALS AND METALLOIDS

The trace metals are presented in alphabetical order in the following sections. All data for individual samples are in a limited number of final reports from the analytical laboratory, and on the Ministry of Environment computerized data storage and retrieval system. Discussion of metals is limited to those considered to be priority toxicants.

Eight digestion blank samples were analyzed for all metals. For contamination to be present, measurable quantities would be present in these digestion blanks. None were measured above the following detection limits (dry-weight) except for one iron (1.5 µg/g) and one magnesium (0.54 µg/g):

As	0.01 µg/g	Cd, Cu, Mn, Zn	0.1 µg/g
Cr, Ni	0.5 µg/g	Fe, Pb, Mo,	1.0 µg/g
Mg,	0.2 µg/g	Hg	0.005 µg/g

Since little or no contamination appears to be present due to the digestion process, corrections were not made to the data values reported by the laboratory.

3.2.1 ARSENIC

For accuracy of arsenic values in sediments, three different standard sediment types were analyzed. These were two types of marine sediments from the National Research Council of Canada and an estuarine sediment from the National Bureau of Standards (USA). In terms of accuracy (Figure 2(a)), arsenic values in sediments were generally within the certified range of values or ever so slightly below. In terms of analytical precision, as determined using duplicate analyses of different sediment samples from the surveys, values were generally within 10% of each other.

Thus, these data indicate that the results reported here for arsenic are generally accurate and precise within 10% for sediments.

Arsenic concentrations ranged from a minimum of 2.89 µg/g at Site MS-2 at Sapperton Channel in the Main Stem to a maximum of 10.9 µg/g at Site NA-2 at McDonald Slough in the North Arm. Finding the highest concentration at the McDonald Slough site is not unexpected, due to the high organic carbon content and small particle size found at this site.

In the 1985 and 1987 surveys, arsenic could not be detected in sediments; however, the detection limits were 25 and 30 µg/g, respectively(Swain 1986, and Swain and Walton 1988). In both the North and Main arms, the mean arsenic concentration was slightly higher at the downstream sampling site. This was likely due to the slightly smaller particle sizes of the sediments at these sites and the associated sorption onto the larger relative surface areas of the sediments.

Mean arsenic concentrations decreased in a downstream direction in the Main Stem, but increased in a downstream direction in both the Main and North arms.

3.2.2 CADMIUM

For accuracy of cadmium values in sediments, three different standard sediment types were analyzed as for arsenic (Section 3.2.1)(two types of marine sediments from the National Research Council of Canada and an estuarine sediment from the National Bureau of Standards (USA)). In terms of accuracy (Figure 2(b)), cadmium values in sediments were generally within the certified range of values or ever so slightly below. In terms of analytical precision, as determined using duplicate analyses of different sediment samples from the surveys (Figure 3 (b)), values were generally within 10% of each other at concentrations greater than 0.5 µg/g (dry-weight) and within 20% of each other below this concentration.

Thus, these data indicate that the results reported here for cadmium were accurate and generally precise within 10%.

During this survey, cadmium concentrations ranged from a minimum of 0.20 µg/g at Sites MS-1 at Barnston Island in the Main Stem and MA-2 at Ewen Slough in the Main Arm to a maximum of 0.38 µg/g at Site NA-1 at Upper North Arm. Finding the highest concentration at the Upper North Arm site is surprising, due to the high organic carbon content and small particle size found further downstream at the McDonald Slough site. However, a closer examination of the cadmium data from the two North Arm sites indicates that the concentrations at these two sites are virtually the same.

The 1989 results were similar to those reported for the 1985 survey (Swain 1986). During the 1987 survey, cadmium could not be detected below the detection limit of 0.3 µg/g (Swain and Walton 1988). Since accuracy and precision data are not available for the 1987 results, it is not known whether the slightly higher cadmium concentrations in the sediments in 1989 reflected a true increase in concentration or reflect laboratory and analytical differences.

Mean cadmium concentrations decreased very slightly in a downstream direction in the Main Stem and in both the Main and North arms.

3.2.3 CHROMIUM

For accuracy of chromium values in sediments, three different standard sediment types were analyzed (two types of marine sediments from the National Research Council of Canada and an estuarine sediment from the National Bureau of Standards (USA)). In terms of accuracy (Figure 2(c)), chromium values in sediments were well outside and below the certified range of values. In terms of analytical precision as determined using duplicate analyses of different sediment samples from the surveys (Figure 3 (c)), values were generally within 10% of each other at concentrations greater than 30 µg/g (dry-weight) and within 20% of each other below this concentration.

Thus, these data indicate that the results reported here for chromium are usually low and would not be considered to be accurate, but were generally precise within 10 to 20%, depending upon the concentration.

Chromium concentrations ranged from a minimum of 45.6 µg/g at Site MS-1 at Barnston Island in the Main Stem (Table 2) to a maximum concentration of 60.6 µg/g at Site NA-2 at McDonald Slough (Table 5) in the North Arm. Finding the highest concentration at the McDonald Slough site is not unexpected, due to the high organic carbon content and small particle size found at this site.

The maximum chromium concentration in the 1987 survey was 45 µg/g at McDonald Slough (Swain and Walton 1989). The chromium concentrations in the 1989 survey were generally about twice those found in the 1985 (Swain 1986) or the 1987 surveys; however, the sediment particle size in 1989 was finer than in 1987 and the same or slightly finer than in 1985, which partly explains the differences in concentrations. As well, the fact that two different laboratories analyzed the samples by two different techniques has to be considered.

Mean chromium concentrations decreased in a downstream direction in the Main Stem and the Main Arm, but increased in a downstream direction in North Arm. In the 1987 survey, mean chromium concentrations increased in a downstream direction in each of the main reaches (Swain and Walton 1988). This difference between the two surveys may be a reflection of the flushing of finer

particles from downstream sites (except the sheltered McDonald Slough) prior to sampling in August 1989.

3.2.4 COPPER

For accuracy of copper values in sediments, three different standard sediment types were analyzed (two types of marine sediments from the National Research Council of Canada and an estuarine sediment from the National Bureau of Standards (USA)). In terms of accuracy (Figure 2(d)), copper values in sediments were within the certified range of values. In terms of analytical precision, as determined using duplicate analyses of different sediment samples from the surveys (Figure 3 (d)), values were generally within 10 to 15% of each other at all concentrations.

Thus, these data indicate that the results reported here for copper are within the certified range of values and would be considered to be accurate. They were generally precise within 15%, depending upon the concentration.

The copper concentrations found in the sediments collected in 1989 ranged from a low of 25.4 µg/g at Site MS-2 at Sapperton Channel in the Main Stem to 58 µg/g at Site NA-2 at McDonald Slough in the North Arm. Finding the highest concentration at the McDonald Slough site is not unexpected, due to the high organic carbon content and small particle size found at this site.

As was the case for chromium, copper concentrations in 1989 were considerably higher than in 1987 (Swain and Walton 1988); however, this may be due to finer particles being present in 1989 than in 1987 or the fact that different laboratories performed the analyses. Compared to the 1985 survey (Swain 1986), the mean concentrations at four of the six sites were nearly identical; however, the mean concentrations in 1989 at MS-1 and NA-2 were about 50% or more higher.

Mean copper concentrations decreased in a downstream direction in the Main Stem and Main Arm, but increased in a downstream direction in the North Arm. In the 1987 survey, mean concentrations decreased in a downstream direction in the Main Stem and North Arm, but increased in a downstream direction in the Main Arm (Swain and Walton 1988). Whereas we concluded that the differences between surveys for chromium might have been

attributable to the time of year that the samples were collected, we cannot make the same conclusion for copper.

3.2.5 LEAD

For accuracy of lead values in sediments, three different standard sediment types were analyzed (two types of marine sediments from the National Research Council of Canada and an estuarine sediment from the National Bureau of Standards (USA)). In terms of accuracy (Figure 2(f)), lead values in sediments were within the certified range of values for most of the reference sediments but slightly lower than the certified range for the estuarine reference sediment. In terms of analytical precision, as determined using duplicate analyses of different sediment samples from the surveys (Figure 3 (f)), values were generally within 15% of each other at all concentrations.

Thus, these data indicate that the results reported here for lead are within the certified range of values except for the estuarine reference sample. They were generally precise within 15%, depending upon the concentration.

Lead concentrations ranged from a minimum of 6.55 µg/g at Site MS-1 at Barnston Island in the Main Stem (Table 2) to 24 µg/g at Site NA-2 at McDonald Slough in the North Arm (Table 5). Finding the highest concentration at the McDonald Slough site is not unexpected, due to the high organic carbon content and small particle size found at this site.

Mean lead concentrations in 1989 generally were slightly lower than found in 1985 (Swain 1986) or in 1987 (Swain and Walton 1988). This may reflect the declining use of lead in gasoline, since it would be anticipated based upon particle size that the 1989 lead concentrations should have been higher than those found in 1987.

Mean lead concentrations decreased in a downstream direction in the Main Stem and Main Arm, but increased in a downstream direction in North Arm. In 1987, the reverse was true in each of the main reaches (Swain and Walton 1988). As we concluded for chromium, this may reflect differences due to the time of year that the samples were collected.

3.2.6 MERCURY

For accuracy of mercury values in sediments, three different standard sediment types were analyzed (two types of marine sediments from the National Research Council of Canada and an estuarine sediment from the National Bureau of Standards (USA)). In terms of accuracy (Figure 2(i)), mercury values in sediments were within the certified range of values or higher than the reference sediments. In terms of analytical precision, as determined using duplicate analyses of different sediment samples from the surveys (Figure 3 (i)), values were generally within 20% of each other at all concentrations.

Thus, these data indicate that the results reported here for mercury are within the certified range of values or higher than the range. They also were generally precise within 20%.

Mercury concentrations in 1985 (Swain 1986) and 1987 (Swain and Walton 1988) were about the same; in the range of about 0.06 to 0.07 µg/g. In the 1989 survey, this was also generally the situation. The maximum mercury concentration in the 1989 survey was 0.091 µg/g at Site NA-2 at McDonald Slough in the North Arm (Table 5). Finding the highest concentration at the McDonald Slough site is not unexpected, due to the high organic carbon content and small particle size found at this site. The lowest mercury concentration was 0.039 µg/g at Site MS-2 at Sapperton Channel in the Main Stem (Table 3), the site with the largest quantity of coarse particles and lowest organic carbon content.

Mean mercury concentrations decreased in a downstream direction in the Main Stem, but increased in a downstream direction in both the Main and North arms. Increases in mean mercury concentrations were noted in each of the three main reaches in 1987 (Swain and Walton 1988). Whereas we concluded that the differences between surveys for some metals might have been attributable to the time of year that the samples were collected, we cannot make the same conclusion for mercury (or copper).

3.2.7 NICKEL

For accuracy of nickel values in sediments, three different standard sediment types (two types of marine sediments from the National Research Council of Canada and an estuarine sediment from

the National Bureau of Standards (USA)) were used. In terms of accuracy (Figure 2(k)), nickel values in sediments were below the certified range of values for the reference sediments. In terms of analytical precision, as determined using duplicate analyses of different sediment samples from the surveys (Figure 3 (k)), values were generally within 10% of each other at all concentrations.

Thus, these data indicate that the results reported here for nickel are below the certified range of values and generally precise within 10%.

Very little difference existed in nickel concentrations among the sites in 1989, with the minimum value at most sites being about 50 µg/g and the maximum about 55 µg/g. These concentrations are about 10 µg/g higher than found in 1985 (Swain 1986) or in 1987 (Swain and Walton), and are likely attributable to the differences in particle sizes of the sediments and the fact that two different laboratories performed the analyses using different analytical techniques.

Mean nickel concentrations decreased in a downstream direction in the Main Stem and Main Arm, but increased in a downstream direction in the North Arm. In the 1987 survey, the mean concentrations increased in a downstream direction in the Main Stem and the Main Arm, but were unchanged in the North Arm (Swain and Walton 1988). As we concluded for chromium and lead, this may reflect differences due to the time of year that the samples were collected.

3.2.8 ZINC

For accuracy of zinc values in sediments, three different standard sediment types were analyzed as for arsenic (Section 3.2.1)(two types of marine sediments from the National Research Council of Canada and an estuarine sediment from the National Bureau of Standards (USA)). In terms of accuracy (Figure 2(l)), zinc values in sediments were within or just slightly below the certified range of values for the reference sediments. In terms of analytical precision, as determined using duplicate analyses of different sediment samples from the surveys (Figure 3 (l)), values were generally within 15% and usually less than 10% of each other at all concentrations.

Thus, these data indicate that the results reported here for zinc are within or slightly below the certified range of values. They were generally precise within 10%.

As was the case for most other metals analyzed, zinc concentrations in 1989 were considerably higher than found at the same sites in the 1985 (Swain 1986) or the 1987 surveys (Swain and Walton 1988). In 1989, zinc concentrations ranged from a minimum of 62.2 µg/g at Site MS-2 at Sapperton Channel in the Main Stem (Table 3) to a maximum of 220 µg/g at Site NA-1 in the Upper North Arm (Table 4). Since the highest zinc concentrations were expected at the McDonald Slough site, one suspects that there is a local source of zinc to the Upper North Arm.

In fact, the discharge from Tree Island Steel has high zinc concentrations (Supervisory Coordinating Committee 1987) and is located in close proximity to the Upper North Arm site.

Mean zinc concentrations in the 1989 survey decreased in a downstream direction in the Main Stem, and in both the Main and North arms. In the 1987 survey, mean concentrations increased in the North and Main arms but decreased slightly in the Main Stem (Swain and Walton 1988). As we concluded for chromium, lead, and nickel, this may reflect differences due to the time of year that the samples were collected.

3.2.9 CONCLUSIONS

Concentrations of metals measured in sediments in 1989 were usually higher than found in the sediments from the same sites in 1987; this may be explained by the fact that the sediment particle size in 1989 was finer than in 1987, that different laboratories and techniques were used in the two years, or that the time of year that samples were collected was a factor. Finer sized particles have large surface areas onto which contaminants can be sorbed, so the higher metal concentrations may be attributable to this phenomenon rather than to increased anthropogenic inputs of metals.

The one exception to higher metals concentrations in 1989 compared to 1987 was lead, for which 1989 concentrations were actually lower than in 1987, when the reverse was expected. This

suggests that the elimination of lead from gasoline is having a positive environmental impact.

It is suspected that the particle size of the sediments is related to the time of year that the sediments were collected. In fact, we concluded that chromium, lead, nickel, and zinc concentrations also may reflect differences due to the time of year that the samples were collected. This was based on whether patterns for increases or decreases of the concentrations of these metals was the same in the 1987 and 1989 surveys. Such a conclusion could not be drawn for cadmium, copper, or mercury.

3.3 CHLORINATED PHENOLS AND PCBs

3.3.1 Quality Assurance / Quality Control

Quality assurance of chlorophenols and PCBs involved checking for contamination following extraction, using spiked samples to determine percent recoveries, and performing duplicate analyses. To check for contamination in the extraction procedure, ten blank samples were used, while to check the percent recovery, ten spiked sediment samples were used. Contamination was not found in any extraction samples for sediments which were below detection. Detection limits were as follows:

	SEDIMENTS
trichlorophenol	0.005 µg/g
tetrachlorophenol	0.005 µg/g
pentachlorophenol	0.005 µg/g
PCBs	0.010 µg/g

The following are the percent recoveries of spiked samples at concentrations of ten times the detection limit.

	Percent Recoveries (%) **SEDIMENTS**	
	Range	Mean
trichlorophenol	64.5-133	85.6
tetrachlorophenol	66.5-115	87.1
pentachlorophenol	59.1-112	83.7
PCBs	64 - 93	83.3

The spiked samples consisted of the organic in question being put into a solvent, and indicate possible losses in the analytical process past the point of extraction. Due to the artificial nature of this quality control process, losses which exist for the spike would not necessarily occur in the analysis of the actual sample. Therefore the percent recoveries may indicate a "worst-case" scenario. For this reason, no corrections have been applied to the data, and these recovery data will only be taken into account when examining whether Water Quality Objectives are achieved.

Eleven duplicate sediment analyses were performed. All duplicates except one were below the detection limits of 0.005 µg/g for each of the chlorophenols and 0.010 µg/g for PCBs. The one exception was a duplicate pentachlorophenol analysis, each of the duplicates being at the detection limit.

3.3.2 Values in Sediments

All three forms of chlorophenols (tri-, tetra-, and penta-) were less than the detection limit (0.005 µg/g) at all six sites (Table 8). A lower detection limit (0.003 µg/g) was used in the 1987 survey (Swain and Walton 1988), and so direct comparisons between these two years cannot be made. However, the 1987 data were lower than concentrations found in 1985 at the same sites. It is not possible to determine with complete certainty if the Water Quality Objective of a maximum 0.01 µg/g chlorophenol in sediment was achieved in the 1989 survey due to the detection limits used.

PCBs could not be detected (<0.01 µg/g) at any of the sites in this survey (Table 8). This was also the case in 1987 at the same sites when the detection limit was 0.02 µg/g (Swain and Walton 1988), although PCBs had been detected at Barnston Island in the Main Stem and at both sites in the North Arm in 1985. The Water Quality Objective for PCBs in sediment of 0.03 µg/g maximum was achieved at all the sites in this survey.

3.3.3 CONCLUSIONS

Laboratory quality assurance data indicated that all extraction samples were below detection and thus uncontaminated.

PCBs could not be detected (<0.01 µg/g) at any of the sites in this survey as was the case in 1987 for the same sites when the

detection limit was 0.02 µg/g. The Water Quality Objective for PCBs in sediment of 0.03 µg/g maximum was achieved at all the sites in this survey.

3.4 PHTHALATE ESTERS

3.4.1 Quality Assurance / Quality Control

Phthalic acid esters represent a large family of organic chemicals used widely as plasticizers (Leah 1977). Six phthalate esters were measured in this survey. These were dimethyl, diethyl, di-n-butyl, butyl benzyl, di-n-octyl, and bis (2-ethylhexyl). Quality assurance of phthalate esters involved checking for contamination following extraction using ten blank samples, and checking the percent recovery of the ten spiked sediment samples. Contamination was found in the extraction blanks, as follows.

Contamination was present for each of the phthalate esters in at least one extraction blank, except for dimethyl phthalate and butyl benzyl phthalate. The following levels were detected in the extraction blanks:

Phthalate Ester	No. of Blank Samples with Detectable Values (of 10)	Measured Values (µg/g dry weight)
Diethyl	1	0.11
Di-n-butyl	4	0.15,0.19, 0.16,0.15
Di-n-octyl	1	0.17
Bis (2-ethylhexyl)	3	0.15,0.18,0.26

Only when phthalate esters are present in sediments at concentrations greater than the above maximum concentrations for each phthalate ester will it be considered possible that phthalates are present in the sediments, and not simply an artifact of the laboratory analyses.

Percent recoveries for spiked samples at concentrations ten times the detection limit were as follows:

Phthalate Ester	Sediments (% Recoveries) Range	Mean	Std. Dev.
Dimethyl	56.8-98.5	79.2	12.3
Diethyl	50-115	77.4	18.6
Butyl Benzyl	81-116	97.6	11.4
Di-n-octyl	56.6-127	82.5	21.4

The spiked samples consist of the organic in question being put into a solvent, and indicate possible losses in the analytical process past the point of extraction. Due to the artificial nature of this quality control process, losses which exist for the spike do not necessarily occur in the analysis of the actual sample. Therefore the percent recoveries likely indicate a "worst-case" scenario. For this reason, no corrections have been applied to the data.

Duplicate analyses were also performed for 11 sediment samples for the six phthalate esters. Normally, the six phthalates were below the detection limit of 0.10 µg/g dry-weight. However, the following differences were determined:

Phthalate Ester	Duplicate #1		Duplicate #2		Duplicate #3		Duplicate #4		Duplicate #5	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Diethyl	<0.1	0.29	0.47	0.21	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Di-n-butyl	0.16	0.29	<0.1	0.24	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Bis (2-ethylhexyl)	0.81	0.97	0.18	0.51	<0.1	0.63	0.11	0.10	0.55	0.43
						Duplicate #6			0.51	0.58

These data point out that the precision of the diethyl, di-n-butyl, and bis (2-ethylhexyl) phthalate analyses is poor, likely due to the contamination problems noted for the extraction blanks.

3.4.2 VALUES IN SEDIMENTS

Data for the phthalate esters are summarized in Table 9. Phthalate esters had not been measured in the 1985 or 1987 surveys. The values measured in sediments in 1989 were usually below the detection limit for the particular phthalate or below the level of

contamination cited for each phthalate in Section 3.4.1. Exceptions to this were the maximum concentration of 0.47 µg/g di-n-butyl phthalate measured at Site NA-2 in McDonald Slough in the North Arm; maximum di-n-octyl phthalate concentrations of 0.37 µg/g at Site MS-1 at Barnston Island in the Main Stem and 0.23 µg/g at Site MA-2 at Ewen Slough in the Main Arm; and the maximum bis(2-ethylhexyl) phthalate concentrations at all sites except MS-2 (n=1) at Sapperton Channel in the Main Stem. Based on particle size of the sediments and the organic carbon content, the highest concentrations of phthalates would be expected at the McDonald Slough site in the North Arm. The fact that this was not evident raises the question as to whether there is a major source of phthalates to the river, although the ubiquitous nature of phthalates and the problems of analysis of phthalates are factors which cloud this issue.

AET values have been developed for Puget Sound Department of Ecology 1986) for phthalate esters. The lowest AETs were 0.07 µg/g for dimethyl phthalate, 0.05 µg/g for diethyl phthalate, 1.4 µg/g for di-n-butyl phthalate, 0.06 µg/g for butyl benzyl phthalate, >0.4 µg/g for di-n-octyl phthalate, and 1.9 µg/g for bis(2-ethylhexyl) phthalate. All phthalate ester concentrations measured in the Fraser River sediments above contamination levels were below the lowest AET concentrations.

3.4.3 CONCLUSIONS

Contamination was present for phthalates for sediments in quality control samples. Precision of the analytical procedure was poor, but this may have been the result of the contamination which was associated with these characteristics.

Measuring phthalates in the environment is difficult due to their ubiquitous nature which produces sample contamination. Concentrations of phthalates measured in this survey were usually below the detection limit for the particular phthalate or below the level of contamination cited for each phthalate from the quality control data. Exceptions to this were the maximum concentrations of di-n-butyl phthalate, di-n-octyl phthalate, and bis (2-ethylhexyl) phthalate. Apparent Effects Threshold (AET) values have been developed for Puget Sound Department of Ecology for phthalate esters. All phthalate ester concentrations measured in the Fraser

River sediments above contamination levels were below the lowest AET concentrations.

3.5 POLYCYCLIC AROMATIC HYDROCARBONS (PAHs)

3.5.1 Quality Assurance / Quality Control

PAHs are commercially-used compounds, are naturally present in coal and petroleum, and are also formed during the incomplete combustion of hydrocarbons (Garrett 1982). PAHs measured in this survey included acenaphthene, acenaphthylene, anthracene, benzo (a) anthracene, benzo (a) pyrene, benzo (b) fluoranthene, benzo (g,h,i) perylene, benzo (k) fluoranthene, chrysene, dibenzo(a,h)anthracene, fluoranthene, fluorene, indeno (1,2,3-c,d) pyrene, naphthalene, phenanthrene, and pyrene.

Quality assurance of PAHs involved checking for contamination following extraction using ten blank samples, and checking the percent recovery of ten spiked sediment samples. Contamination was found in only one extraction blank (acenaphthylene at 0.013 µg/g). It was not detected in any of the other extraction blanks.

The spiked samples consisted of the organic in question being put into a solvent, and indicate possible losses in the analytical process past the point of extraction. Due to the artificial nature of this quality control process, losses which exist for the spike do not necessarily occur in the analysis of the actual sample. Therefore the percent recoveries may indicate a "worst-case" scenario. For this reason, no corrections have been applied to the data. Percent recoveries for spiked samples at concentrations ten times the detection limit were as follows:

	Sediments (% Recoveries)		
PAHs	Range	Mean	Std. Dev.
Acenaphthene	61.4-112	85.9	16.3
Benzo(a)pyrene	48.4-115	82.8	20.2
Chrysene	55.9-110	82.6	16.8
Dibenzo(a,h)anthracene	61.5-110	86.4	16.9
Fluorene	54.0-106	81.5	16.3
Phenanthrene	66.9-115	91.7	16.1
	Mean	85.1	

For some PAHs in sediments, considerable differences existed between certain duplicate samples. The following duplicate analyses are for detectable analyses since many of the eleven duplicates were less than the detection limit. To simplify the presentation, the values listed under the title "Duplicate" for individual PAHs are not necessarily all for the same sample.

PAH	DUPLICATE	DUPLICATE	DUPLICATE	DUPLICATE
ACENAPHTHENE	<0.005 0.013	0.10 0.13		
ACENAPHTHYLENE	0.042 0.078	<0.005 0.015	0.033 0.035	0.053 0.058
ANTHRACENE	0.02 <0.005	0.031 0.030	0.026 0.018	0.096 0.10
BENZO(A) ANTHRACENE	0.054 <0.01	0.044 <0.01	0.022 <0.01	0.082 0.11
BENZO(A) PYRENE	<0.02 0.026			
BENZO(B) FLUORANTHENE	<0.02 0.049	0.16 0.45	0.027 0.023	<0.02 0.026
BENZO(GHI) PERYLENE	<0.02 0.043	0.046 0.049	0.028 0.048	
BENZO(K) FLUORANTHENE	<0.02 0.038	0.070 0.020		
CHRYSENE	0.054 0.081	0.019 <0.01	<0.01 0.017	
DIBENZO (AH) ANTHRACENE	0.80 0.76			
FLUORANTHENE	0.036 0.018	0.071 0.012	0.52 0.37	0.021 0.033
FLUORENE	0.014 0.020	0.062 0.054	0.039 0.033	
INDENO (1,2,3-CD) PYRENE	0.026 0.032	0.17 0.10		
NAPHTHALENE	0.015 0.012	0.008 <0.005	<0.005 0.011	0.055 0.037
PHENANTHRENE	0.02 <0.005	0.026 0.015	0.082 0.10	0.020 0.025
PYRENE	0.031 0.012	0.014 <0.01	0.021 0.016	<0.010 0.015

PAH	DUPLICATE	DUPLICATE	DUPLICATE
BENZO(B) FLUORANTHENE	0.055 0.065	0.033 0.029	0.069 0.024
FLUORANTHENE	0.46 0.53	0.036 0.018	0.085 0.035
FLUORENE	0.016 <0.005	0.055 0.032	0.005 0.005
PHENANTHRENE	0.26 0.24		
PYRENE	0.46 0.41		

3.5.2 Values in Sediments

Data for the concentrations of PAHs in sediments are summarized in Table 10. PAHs were not measured in the 1987 or 1985 surveys. Generally, most of the individual PAHs in 1989 were below the varying detection limits for the individual PAHs. High values relative to the detection limit, were determined as follows:

PAH	Sediment Concentrations (µg/g dry weight) LOWEST AET	MAXIMUM VALUE	LOCATION
Acenaphthylene	>0.56	0.053	McDonald Slough-N.Arm
Anthracene	0.96	0.070	McDonald Slough-N.Arm
Benzo(a)pyrene	1.6	0.10	Barnston Is.-Main Stem
Benzo(a)pyrene	1.6	0.098	Ewen Slough-Main Arm

These data indicate that the highest PAH concentrations are 10% or less than the lowest AET value for Puget Sound sediments. This means that there is no immediate concern for the concentration of PAHs in Fraser River Estuary sediments. The fact that the highest concentrations of two PAHs were in McDonald Slough in the North Arm is not unexpected, given the fact that the smallest particles and highest organic carbon concentrations were found at this same site.

3.5.3 CONCLUSIONS

Contamination in blank samples was found in only one extraction blank, for acenaphthylene. This was the only PAH detected in sediment blanks. Considerable differences existed between duplicate analyses for some detectable PAHs, although many could not be detected.

Most of the individual PAHs were below the varying detection limits. High values relative to the detection limit were determined for acenaphthylene, anthracene, and benzo (a) pyrene, although the highest PAH concentrations were 10% or less than the AET for Puget Sound sediments. This means that there is no immediate concern for the concentration of PAHs in Fraser River Estuary sediments.

3.6 ORGANOCHLORINE PESTICIDES

Organochlorine pesticides measured in this survey were aldrin, alpha-chlordane, gamma-chlordane, dieldrin, DDT, DDE, DDD, endrin, endosulfan-I, endosulfan-II, endosulfan sulfate, heptachlor, heptachlor epoxide, lindane, methoxychlor, and toxaphene.

3.6.1 QUALITY ASSURANCE / QUALITY CONTROL

Quality assurance for organochlorine pesticides involved checking for contamination following extraction with ten blank samples. As well, the percent recovery for ten spiked sediment samples was checked. Organochlorine pesticides were not detected in any of the extraction blanks for either sediments. The spiked samples do not necessarily indicate losses that would occur in the analyses. The results in the tables have had no corrections made for the recovery data. Percent recoveries for the ten spiked sediment samples were as follows:

Organochlorine Pesticide	Sediment (% Recovery) Range	Mean	Standard Dev.
Aldrin	52.1- 82.9	65.5	11.8
Alpha-Chlordane	50.2- 109	67.9	21
Gamma-Chlordane	51.1- 110	66.8	21.2
Dieldrin	51.0- 97.9	70.5	16.1
DDT	61.1- 101	77.3	13.1
DDD	53.6- 81	68.9	9.4
DDE	60.3- 91.4	72.9	10.0
Lindane	62.9- 85	70.6	7.1
Methoxychlor	58.9- 104	82.7	15.4
		71.4	

3.6.2 VALUES IN SEDIMENTS

The concentrations of organochlorine pesticides in Fraser River sediments are summarized in Table 11. All values for all six sites were less than varying detection limits except for DDD, DDE, and DDT. Only DDE was detected at more than one site (Sites NA-1 in the Upper North Arm and MA-2 in Ewen Slough in the Main Arm). DDD and DDE were both detected at Site NA-1 in the Upper North Arm; however, only DDD was sufficiently (0.005 µg/g) high relative to the detection limit (0.001 µg/g) to be noteworthy. DDT was used in the past as an agricultural pesticide but its use has been banned for many years. Its presence, and that of its breakdown products, likely reflects its historic widespread use. The low concentrations measured indicate that it is becoming degraded.

3.6.3 CONCLUSIONS

Organochlorine pesticides were not detected in any of the extraction blanks.

The concentrations of organochlorine pesticides in Fraser River sediments were less than varying detection limits except for DDD, DDE, and DDT. Only DDE was detected at more than one site, while only DDD was sufficiently high (0.005 µg/g in one sample from one site) relative to the detection limit (0.001 µg/g) to be noteworthy. DDT was used in the past as an agricultural pesticide but its use has been banned for many years. Its presence, and that of its breakdown products, likely reflects its historic widespread use. The low concentrations measured and the presence of the breakdown products indicate that it is becoming degraded.

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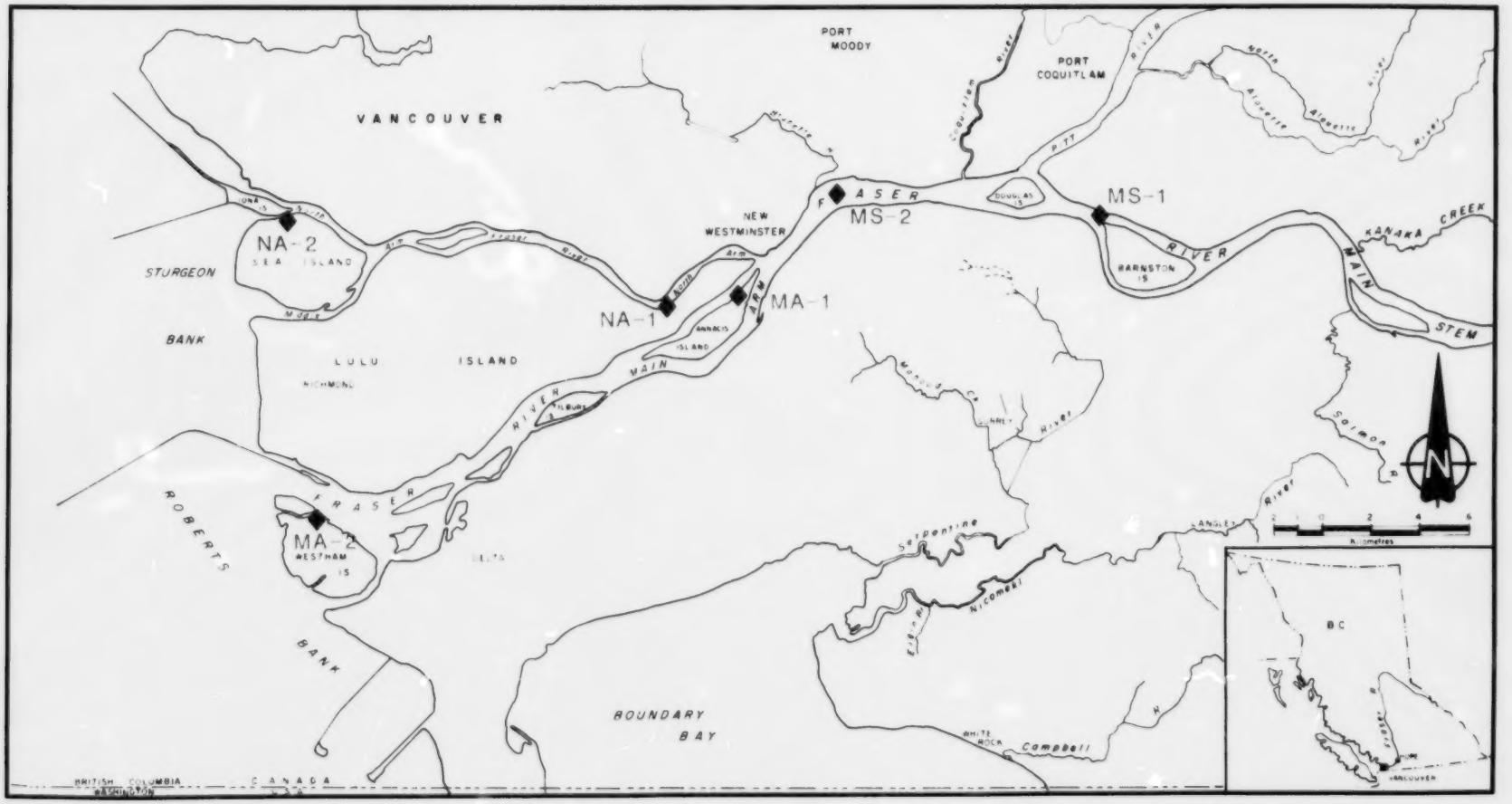

FIGURE 1 SAMPLING SITES-1989

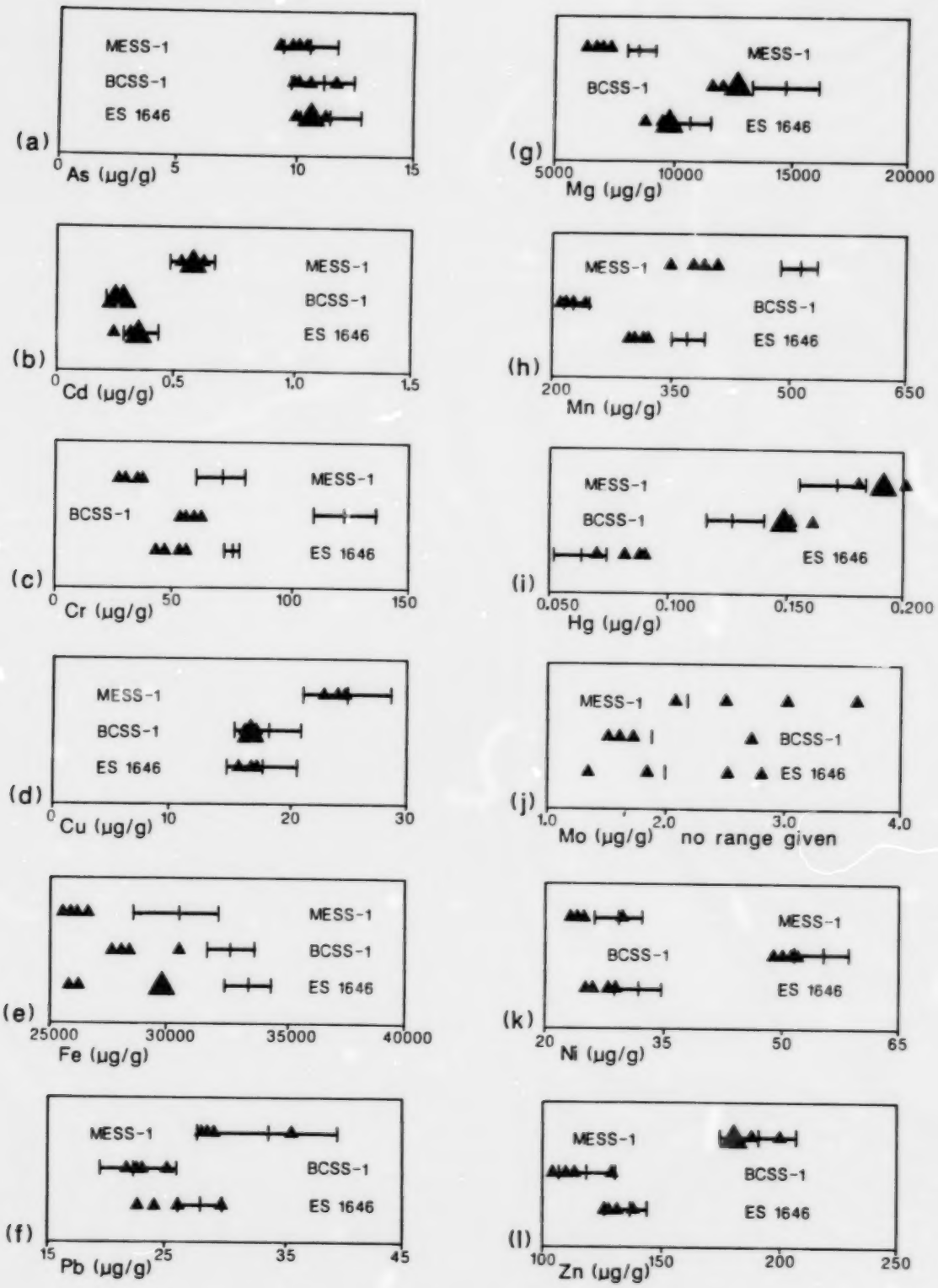

FIGURE 2 ACCURACY DATA FOR SEDIMENTS - 1989 SURVEYS

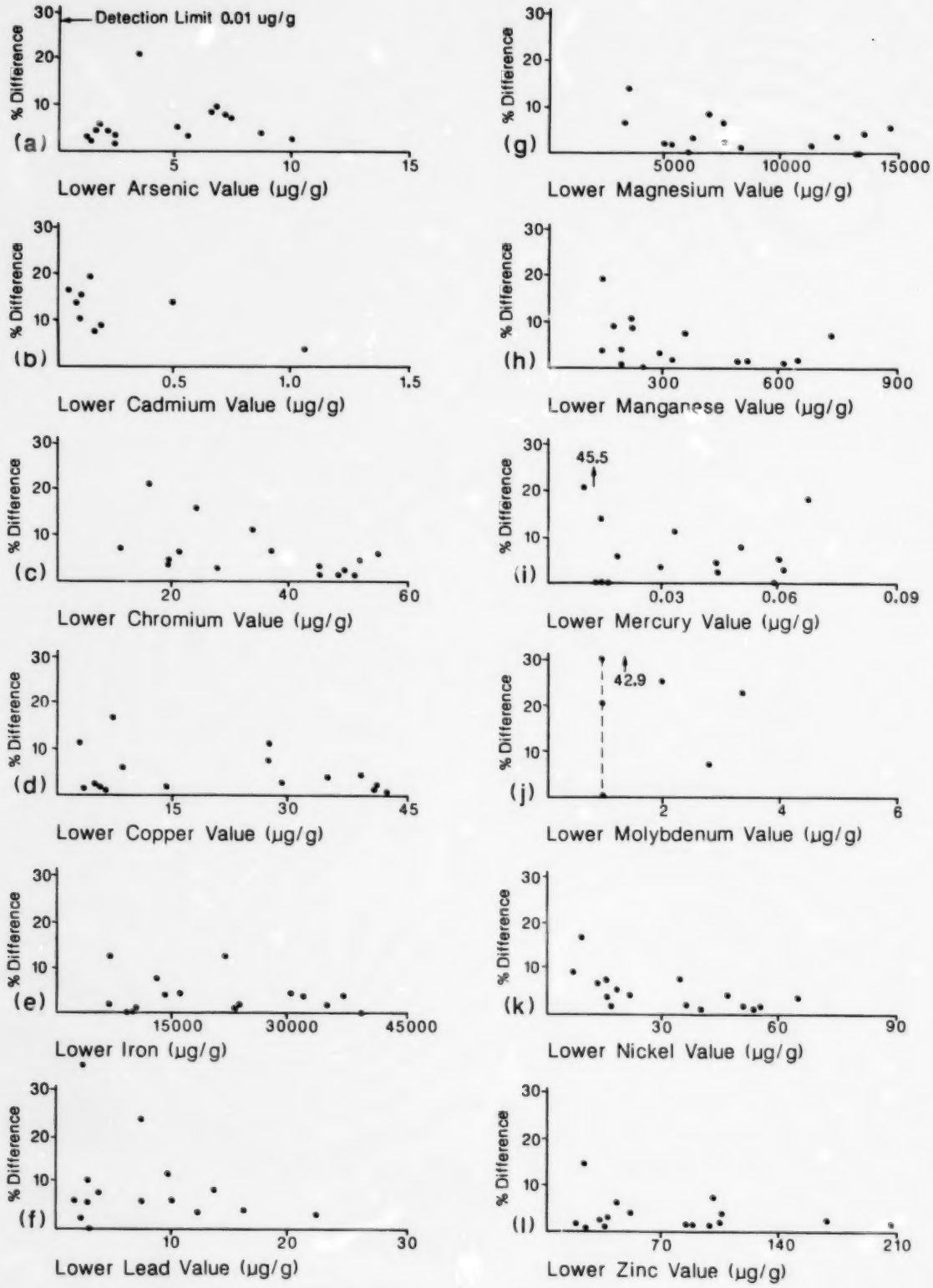

FIGURE 3 COMPARISON OF DUPLICATE ANALYSES FOR SEDIMENTS

TABLE 1

PHYSICAL CHARACTERISTICS OF FRASER RIVER SEDIMENTS

PARTICLE SIZE (% w/w) *		MAXIMUM	MINIMUM	MEAN	STD.DEV.
SITE MS-1	<0.3 mm	61.8	23.5	36.4	16.1
	<0.074 mm	75.9	37.7	63.0	16.1
SITE MS-2	<0.3 mm	37.3	-	-	-
	<0.074 mm	45.7	-	-	-
SITE NA-1	<0.3 mm	22.7	0.2	6.4	9.27
	<0.074 mm	99.5	76.5	91.6	8.97
SITE NA-2	<0.3 mm	0.4	0.0	0.2	0.158
	<0.074 mm	100.0	99.6	99.7	0.239
SITE MA-1	<0.3 mm	0.5	0.0	0.175	0.222
	<0.074 mm	100.0	99.8	99.9	0.082
SITE MA-2	<0.3 mm	0.1	0.0	0.04	0.055
	<0.074 mm	100.0	99.9	99.96	0.057

MOISTURE CONTENT (% w/w "as is")	MAXIMUM	MINIMUM	MEAN	STD.DEV.
SITE MS-1	38.0	34.6	36.3	1.49
SITE MS-2	30.5	-	-	-
SITE NA-1	48.5	39.8	43.6	3.51
SITE NA-2	49.3	47.1	48.4	0.80
SITE MA-1	41.4	34.1	37.9	2.98
SITE MA-2	39.8	33.6	36.3	2.37

TOTAL ORGANIC CARBON (µg/g)	MAXIMUM	MINIMUM	MEAN	STD.DEV.
SITE MS-1	6900	6200	6640	297
SITE MS-2	4600	-	-	-
SITE NA-1	8700	6900	7820	719
SITE NA-2	12500	10300	11100	872
SITE MA-1	7100	6600	6850	238
SITE MA-2	9000	5700	7800	1292

TABLE 1 (CONTINUED)

TOTAL INORGANIC CARBON (µg/g)	MAXIMUM	MINIMUM	MEAN	STD.DEV.
SITE MS-1	4900	3800	4260	439
SITE MS-2	3400	-	-	-
SITE NA-1	5800	4600	5140	568
SITE NA-2	8300	6300	7280	791
SITE MA-1	5100	3600	4425	624
SITE MA-2	500	400	440	55

TOTAL VOLATILE RESIDUE (% w/w)	MAXIMUM	MINIMUM	MEAN	STD.DEV.
SITE MS-1	3.7	3.0	3.3	0.27
SITE MS-2	2.3	-	-	-
SITE NA-1	4.3	3.4	3.8	0.36
SITE NA-2	5.7	4.5	5.1	0.45
SITE MA-1	4.0	3.4	3.6	0.27
SITE MA-2	4.4	2.9	3.5	0.59

NUMBER OF VALUES : 5 AT SITE MS-1
: 1 AT SITE MS-2
: 5 AT SITE NA-1
: 5 AT SITE NA-2
: 4 AT SITE MA-1
: 5 AT SITE MA-2

* Values indicated as being <0.3 mm are those which passed this sieve but were > 0.074 mm. The fraction greater than 0.3 mm is the difference between 100% and the total reported for <0.3 and <0.074 mm.

SITES SAMPLED AUGUST 6, 1989 WERE MA-1, MA-2, AND NA-1
SITES SAMPLED AUGUST 30, 1989 WERE MS-1, MS-2, AND NA-2

TABLE 2
SUMMARY OF METALS IN SEDIMENTS AT SITE MS-1
FRASER RIVER AT BARNSTON ISLAND

METAL	MAXIMUM	(µg/g dry-weight) MINIMUM	MEAN	STD. DEV.
ARSENIC	5.15	4.18	4.74	0.44
CADMIUM	0.24	0.20	0.22	0.019
CHROMIUM	49.6	45.6	47.6	1.55
COPPER	39.2	36.2	37.8	1.34
IRON	34600	30400	33160	1756
LEAD	9.17	6.55	8.02	1.13
MAGNESIUM	13900	12900	13500	430.1
MANGANESE	728	654	697	27.3
MERCURY	0.064	0.044	0.050	0.008
MOLYBDENUM	2.1	<1	<1+	-
NICKEL	55.1	50.9	53.5	1.85
ZINC	93.6	83.1	89.1	4.33

NUMBER OF VALUES: 5 SAMPLED : AUGUST 30, 1989

+ MEDIAN VALUE

TABLE 3
SUMMARY OF METALS IN SEDIMENTS AT SITE MS-2
FRASER RIVER AT SAPPERTON CHANNEL

METAL	(µg/g dry-weight) MAXIMUM	MINIMUM	MEAN	STD. DEV.
ARSENIC	2.89	-	-	-
CADMIUM	0.21	-	-	-
CHROMIUM	40.7	-	-	-
COPPER	25.4	-	-	-
IRON	26600	-	-	-
LEAD	6.90	-	-	-
MAGNESIUM	10000	-	-	-
MANGANESE	537	-	-	-
MERCURY	0.039	-	-	-
MOLYBDENUM	<1	-	-	-
NICKEL	42.9	-	-	-
ZINC	62.2	-	-	-

NUMBER OF VALUES: 1 SAMPLED : AUGUST 30, 1989

TABLE 4
SUMMARY OF METALS IN SEDIMENTS AT SITE NA-1
FRASER RIVER AT THE UPPER NORTH ARM

METAL	(µg/g dry-weight) MAXIMUM	MINIMUM	MEAN	STD. DEV.
ARSENIC	9.92	4.23	7.14	2.38
CADMIUM	0.38	0.29	0.34	0.038
CHROMIUM	55.9	52.3	53.6	1.59
COPPER	43.9	38.7	42.0	1.96
IRON	41800	34400	39780	3121
LEAD	19.1	13.8	15.8	2.14
MAGNESIUM	13300	12700	13020	258.8
MANGANESE	666	551	595.2	45.5
MERCURY	0.066	0.058	0.061	0.0036
MOLYBDENUM	2.5	<1.0	<1.0+	-
NICKEL	55.0	48.8	51.4	2.51
ZINC	220	184	200	14.8

NUMBER OF VALUES: 5

SAMPLED : AUGUST 6, 1989

TABLE 5
SUMMARY OF METALS IN SEDIMENTS AT SITE NA-2
FRASER RIVER AT McDONALD SLOUGH

METAL	(µg/g dry-weight) MAXIMUM	MINIMUM	MEAN	STD. DEV.
ARSENIC	10.9	7.2	9.4	1.48
CADMIUM	0.36	0.26	0.31	0.035
CHROMIUM	60.6	58.6	59.5	0.82
COPPER	58.0	54.9	56.8	1.29
IRON	42400	38700	39740	1514
LEAD	24.0	21.3	22.1	1.12
MAGNESIUM	16000	14900	15260	483
MANGANESE	571	539	553	13.9
MERCURY	0.091	0.077	0.082	0.006
MOLYBDENUM	2.8	<1.0	<1.0+	-
NICKEL	55.2	52.3	53.3	1.23
ZINC	139.	133.	136.8	2.28

NUMBER OF VALUES: 5

SAMPLED : AUGUST 30, 1989

+ MEDIAN VALUE

TABLE 6
SUMMARY OF METALS IN SEDIMENTS AT SITE MA-1
FRASER RIVER AT ANNACIS ISLAND

METAL	(µg/g dry-weight) MAXIMUM	MINIMUM	MEAN	STD. DEV.
ARSENIC	8.21	3.39	5.93	2.32
CADMIUM	0.37	0.26	0.30	0.048
CHROMIUM	55.0	52.2	53.3	1.32
COPPER	42.9	42.2	42.5	0.31
IRON	39100	36400	38025	1147
LEAD	12.6	10.5	11.7	0.9
MAGNESIUM	14100	12900	13375	525
MANGANESE	794	673	709	57.3
MERCURY	0.059	0.052	0.057	0.003
MOLYBDENUM	<1.0	<1.0	<1.0	-
NICKEL	54.6	51.4	52.3	1.54
ZINC	111	104	106.5	3.1

NUMBER OF VALUES: 4

SAMPLED AUGUST 6, 1989

TABLE 7
SUMMARY OF METALS IN SEDIMENTS AT SITE MA-2
FRASER RIVER AT EWEN SLOUGH

METAL	MAXIMUM	(µg/g dry-weight) MINIMUM	MEAN	STD. DEV.
ARSENIC	8.06	5.58	6.94	0.96
CADMIUM	0.32	0.20	0.26	0.058
CHROMIUM	54.4	46.3	50.9	3.10
COPPER	44.2	39.2	41.7	2.01
IRON	37100	33800	35460	1426
LEAD	12.4	9.56	10.8	1.20
MAGNESIUM	14000	12800	13340	451
MANGANESE	554	476	522.6	30.0
MERCURY	0.069	0.056	0.061	0.005
MOLYBDENUM	2.0	<1.0	<1.0+	-
NICKEL	51.8	46.9	49.5	1.78
ZINC	107.	97.9	102.6	3.54

NUMBER OF VALUES: 5 SAMPLED : AUGUST 6, 1989

+ MEDIAN VALUE

TABLE 8
SUMMARY OF CHLOROPHENOLS AND PCBs IN FRASER RIVER SEDIMENTS

CHARACTERISTIC	(µg/g dry-weight) MAXIMUM	MINIMUM	MEAN	STD. DEV.
Trichlorophenol	<0.005	<0.005	<0.005	-
Tetrachlorophenol	<0.005	<0.005	<0.005	-
Pentachlorophenol	<0.005	<0.005	<0.005	-
Polychlorinated Biphenyls	<0.010	<0.010	<0.010	-

NUMBER OF VALUES : 5 AT SITE MS-1
: 1 AT SITE MS-2
: 5 AT SITE NA-1
: 5 AT SITE NA-2
: 4 AT SITE MA-1
: 5 AT SITE MA-2

SITES SAMPLED AUGUST 6, 1989 WERE MA-1, MA-2, AND NA-1
SITES SAMPLED AUGUST 30, 1989 WERE MS-1, MS-2, AND NA-2

TABLE 9
SUMMARY OF PHTHALATE ESTERS IN FRASER RIVER SEDIMENTS

PHTHALATE ESTER*	(µg/g dry-weight) MAXIMUM	MINIMUM	MEAN	STD. DEV
DIMETHYL	<0.10	<0.10	<0.10	-
DIETHYL	<0.10	<0.10	<0.10	-
SITE MA-2	0.12	<0.10	<0.10	-
DI-N-BUTYL	<0.10	<0.10	<0.10	-
SITE NA-1	0.12	<0.10	<0.10+	-
SITE NA-2	0.47	0.10	0.20	0.156
SITE MA-2	0.15	<0.10	<0.10+	-
BUTYL BENZYL	<0.10	<0.10	<0.10	-
DI-N-OCTYL	<0.10	<0.10	<0.10	-
SITE MS-1	0.37	<0.10	<0.10+	-
SITE MA-2	0.23	<0.10	<0.10+	-
BIS(2-ETHYLHEXYL)	<0.10	<0.10	<0.10	-
SITE MS-1	1.44	0.11	0.454	0.57
SITE MS-2	0.19	-	-	-
SITE NA-1	0.64	0.14	0.474	0.20
SITE NA-2	0.71	<0.10	0.526	0.24
SITE MA-1	0.63	0.11	0.410	0.22
SITE MA-2	1.22	0.34	0.692	0.33

* VALUES AT ALL SITES ARE LESS THAN DETECTION UNLESS INDICATED OTHERWISE IN THE TABLE

NUMBER OF SAMPLES : 5 AT SITE MS-1
: 1 AT SITE MS-2
: 5 AT SITE NA-1
: 5 AT SITE NA-2
: 4 AT SITE MA-1
: 5 AT SITE MA-2

+ MEDIAN VALUE

SITES SAMPLED AUGUST 6, 1989 WERE MA-1, MA-2, AND NA-1
SITES SAMPLED AUGUST 30, 1989 WERE MS-1, MS-2, AND NA-2

TABLE 10
SUMMARY OF PAHs IN FRASER RIVER SEDIMENTS

PAH*	MAXIMUM	(µg/g dry-weight) MINIMUM	MEAN	STD. DEV
ACENAPHTHENE	<0.005	<0.005	<0.005	-
ACENAPHTHYLENE	<0.005	<0.005	<0.005	-
SITE MS-1	0.005	<0.005	<0.005+	-
SITE NA-1	0.005	<0.005	<0.005+	-
SITE NA-2	0.053	<0.005	<0.005+	-
ANTHRACENE	<0.005	<0.005	<0.005	-
SITE NA-2	0.070	<0.005	<0.005+	-
BENZO(A)ANTHRACENE	<0.010	<0.010	<0.010	-
SITE MS-1	0.012	<0.010	<0.010+	-
BENZO (A) PYRENE	<0.02	<0.02	<0.02	-
SITE MS-1	0.10	<0.02	<0.02+	-
SITE MA-2	0.098	<0.02	<0.02+	-
BENZO(B)FLUORANTHENE	<0.02	<0.02	<0.02	-
SITE NA-1	0.055	<0.02	<0.02+	-
SITE MA-1	0.051	<0.02	0.036	0.013
SITE MA-2	0.069	<0.02	<0.02+	-
BENZO(G,H,I)PERYLENE	<0.02	<0.02	<0.02	-
SITE NA-1	0.091	<0.02	<0.02+	-
BENZO(K)FLUORANTHENE	<0.02	<0.02	<0.02	-
SITE MA-1	0.06	<0.02	0.03	0.019
SITE MA-2	0.15	<0.02	0.076	0.059
CHRYSENE	<0.010	<0.010	<0.010	-
DIBENZO(A,H)ANTHRACENE	<0.02	<0.02	<0.02	-
SITE MS-1	0.089	<0.02	0.048	0.029
SITE MA-2	0.370	<0.02	<0.02+	-

TABLE 10 (CONTINUED)

PAH*	MAXIMUM	(µg/g dry-weight) MINIMUM	MEAN	STD. DEV
FLUORANTHENE	<0.010	<0.010	<0.010	-
SITE NA-1	0.045	<0.010	<0.010+	-
SITE MA-1	0.036	<0.010	<0.010+	-
SITE MA-2	0.085	<0.010	<0.010+	-
FLUORENE	<0.005	<0.005	<0.005	-
SITE MS-1	0.005	0.005	0.005	-
SITE NA-1	0.005	<0.005	<0.005+	-
INDENO(1,2,3-C,D)PYRENE	<0.02	<0.02	<0.02	-
SITE MS-1	0.098	<0.02	0.044	0.033
SITE NA-1	0.039	<0.02	<0.02+	-
SITE MA-1	0.17	<0.02	<0.02+	-
SITE MA-2	0.32	<0.02	<0.02+	-
NAPHTHALENE	<0.005	<0.005	<0.005	-
SITE MA-2	0.13	<0.005	<0.005	-
PHENANTHRENE	<0.005	<0.005	<0.005	-
SITE MS-2	0.043	-	-	-
SITE NA-1	0.40	<0.005	<0.005+	-
SITE MA-1	0.02	<0.005	<0.005+	-
PYRENE	<0.010	<0.010	<0.010	-
SITE NA-1	0.04	<0.010	<0.010+	-
SITE MA-1	0.021	<0.010	<0.010+	-

* ALL VALUES FOR ALL SITES ARE LESS THAN THE DETECTION LIMIT SHOWN EXCEPT FOR THOSE SITES INDICATED FOR A PARTICULAR PAH.

NUMBER OF VALUES : 5 AT SITE MS-1
: 1 AT SITE MS-2
: 5 AT SITE NA-1
: 5 AT SITE NA-2
: 4 AT SITE MA-1
: 5 AT SITE MA-2

SITES SAMPLED AUGUST 6, 1989 WERE MA-1, MA-2, AND NA-1
SITES SAMPLED AUGUST 30, 1989 WERE MS-1, MS-2, AND NA-2

TABLE 11
SUMMARY OF ORGANOCHLORINE PESTICIDES IN FRASER RIVER SEDIMENTS

ORGANOCHLORINE PESTICIDE*	(µg/g dry-weight) MAXIMUM	MINIMUM	MEAN	STD. DEV
DDT	<0.001	<0.001	<0.001	-
SITE MS-1	0.003	<0.001	<0.001+	-
DDD	<0.001	<0.001	<0.001	-
SITE NA-1	0.005	<0.001	<0.001+	-
DDE	<0.0005	<0.0005	<0.0005	-
SITE NA-1	0.0006	<0.0005	0.0005	0.00004
SITE MA-2	0.0005	<0.0005	<0.0005	-

* ALL VALUES FOR ALL SITES ARE LESS THAN THE DETECTION LIMIT EXCEPT FOR THOSE SITES INDICATED FOR A PARTICULAR ORGANOCHLORINE PESTICIDE. DETECTION LIMITS ARE:

	µg/g		µg/g
ALDRIN	<0.001	ALPHA-CHLORDANE	<0.001
GAMMA-CHLORDANE	<0.001	DIELDRIN	<0.001
ENDRIN	<0.0005	ENDOSULFAN I	<0.001
ENDOSULFAN II	<0.001	ENDOSULFAN SULPHATE	<0.010
HEPTACHLOR	<0.0005	HEPTACHLOR EPOXIDE	<0.010
LINDANE	<0.001	METHOXYCHLOR	<0.005
TOXAPHENE	<0.030		

NUMBER OF VALUES : 5 AT SITE MS-1
: 1 AT SITE MS-2
: 5 AT SITE NA-1
: 5 AT SITE NA-2
: 4 AT SITE MA-1
: 5 AT SITE MA-2

SITES SAMPLED AUGUST 6, 1989 WERE MA-1, MA-2, AND NA-1
SITES SAMPLED AUGUST 30, 1989 WERE MS-1, MS-2, AND NA-2